WPS 0758

Policy, Research, and External Affairs

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International Trade

International Economics Department
The World Bank
August 1991
WPS 758

Is There Excess Co-Movement of Primary Commodity Prices?

A Co-Integration Test

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Tests that cast doubt on the existence of excess co-movement in commodity prices.

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This paper — a product of the International Trade Division, International Economics Department — is part of a larger effort in PRE to explain commodity price behavior and model the global markets for primary commodities. Copies are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Dawn Gustafson, room S7-044, extension 33714 (41 pages).

Commodity analysts and traders have long held the perception that primary commodity prices tend to move together over time — even if they are unrelated commodities (with no cross-price elasticities).

In the case of unrelated commodities, common shocks should account for the co-movement of commodity prices. At issue is whether there is co-movement beyond what can be explained by the common shocks, that is, macroeconomic shocks, as Pindyck and Rotemberg recently suggested.

As a first step, Palaskas and Varangis used the cointegration technique to examine whether there is a long-term stationary relationship between seven unrelated commodity prices. All tests accepted the hypothesis of co-movement between all commodity pairs.

In their second step, they used the results from the cointegration to build error correction models for each of the commodities. They used the error correction models to examine the hypothesis of short-run excess co-movement — that is, co-movement above and beyond what can be explained by shocks with common effects (macroeconomic variables).

With some exceptions, the tests cast doubt on the existence of excess co-movement in commodity prices. When they used monthly data for most of the commodities tested, neither the macroeconomic variables nor the other commodity prices explain much of the variation in a commodity price.

In monthly series, however, the tests applied may be inappropriate, given the existence of non-normality in the regression errors. In other words, the tests applied have the wrong size. Using annual data, the explanatory power of the macroeconomic variables increases significantly, but other commodity prices still do not contribute much in explaining the variations of a commodity price.

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I. INTRODUCTION *

It is a common perception that primary commodity prices tend to move together. This perception is especially common among commodity traders who may justify an increase in the price of one commodity because the prices of other commodities have increased. This commodity price co-movement can be identified among commodities that seem unrelated in terms of production or consumption substitutability or complementarity. But there is no *a priori* reason for believing that prices of unrelated commodities should move together, except for macroeconomic shocks affecting commodity markets in general. 1/ For example, in a recession commodity prices decline across the board because demand declines; and in periods of general inflation commodity prices rise, partly because commodities provide a hedge against inflation. However, after accounting for macroeconomic shocks, is co-movement among commodity prices still evident?

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* For useful discussion we wish to thank David Hendry, Pravin Trivedi and Ron Duncan. We also wish to thank Vikran Nehru for his helpful comments.

1/ Barnhart (1989), Chambers and Just (1982), Gilbert (1989), Gilbert and Palaskas (1990), Boughten and Branson (1988), Frankel and Hardouvelis (1985), and Holthan (1988).

Pindyck and Rotemberg (1988) found co-movement of commodity prices beyond what could be explained by the effects of past, current or expected future values of macro-economic variables such as inflation, industrial production, interest rates or exchange rates. They attribute this excess co-movement to either "herd" behavior in commodity markets, or to the absence of some important macroeconomic variable(s) from their analysis. However, they doubt the second explanation, without completely ruling it out, because they experimented extensively with macroeconomic variables. An important point in Pindyck and Rotemberg's results is that the behavior of the excess co-movement differs when tested using low-frequency (annual) data compared with higher-frequency (quarterly/monthly) data. As they moved from low- to higher-frequency observations the amount of co-movement attributed to macroeconomic variables increased and excess co-movement decreased. Maddala (1990) uses Pindyck and Rotemberg's results to suggest that in the formation of price expectations, prices of even unrelated commodities should be taken into account.

In this paper, we test for co-movement and excess co-movement of primary commodity prices using the econometric tests of co-integration in times series and the resulting error-correction models (ECM). The use of co-integration to test the intertemporal properties of commodity prices and their residuals--after accounting for the effects of macroeconomic variables--"cleans-up" the dynamics of the error-term, reduces their serial correlation (a problem with the Pindyck and Rotemberg specification) and in general leads to better specification of the errors to be used for testing excess co-movement. The ECMs will be used to examine the existence of short-run excess co-movement between commodity prices, taking into consideration the long-run relationship between them. In the presence of co-integration the ECM leads to more efficient parameter estimates. In our analysis we choose also to look at pairwise tests as opposed to a groupwise (joint) test. In a groupwise test, one very significant pair can lead to the rejection of the no excess co-movement hypothesis. A simple example is the impact of a single high t-statistic in a joint F-test, when other components of the null hypothesis would not be rejected if tested separately.

The remainder of this paper is structured as follows. In section II, the technique for testing the co-movement of unrelated primary commodities is presented and tests are performed on annual and monthly data. In section III, error-correction models (ECM) for each of the commodities are specified and used to test for excess co-movement between commodity prices. Section IV presents the summary and conclusions.

II. TESTING FOR COMMODITY PRICE CO-MOVEMENT USING CO-INTEGRATION TESTS

The issue of commodity price co-movement is examined first in terms of the long-run. Over the past two decades, commodity prices in nominal terms have shown a persistent tendency to move together. The 1970s saw primary commodity prices generally rising, while during the 1980s primary commodity prices generally declined. The most plausible explanations for these long-run movements of commodity prices have to do with the effects of macroeconomic variables, such as interest rates, exchange rate, and income growth in industrial countries. Alogoskoufis et al. (1990) attribute much of the commodity price upswing during the 1970s to the low interest rates accompanying expansionary monetary policies in industrial countries, while restrictive monetary policies and expansionary fiscal policies opposite could explain the fall of commodity prices during the 1980s. It also appears that this co-movement arises also because all of the prices are nominal, as distinct from real.

In this section, the paper uses co-integration tests to examine the hypothesis that the prices of largely unrelated commodities have a persistent tendency to move together in the long-run. The hypothesized relationship between two commodity price series can be represented in the following form:

$$Y_t - K X_t = Z_t$$

where Y_t and X_t are the logarithms of two commodity prices, Z_t represents the short-run deviations from their long-run relationship, and K is a constant. A necessary condition for Y, X to be cointegrated, i.e., move together, is that the term Z_t defines a stationary process. If Z_t is non-stationary, it will tend to get larger over time and Y_t and X_t will diverge without bounds, that is, they will not co-move. For the purpose of this paper we consider a series stationary if we reject the hypothesis of a unit root in that series. Thus, a test of whether the series Z_t is stationary is to test for the existence of a unit root in the series (see Dickey and Fuller 1979, and Granger and Engle 1985).

Testing for the existence of a stationary relationship between X and Y involves the use of co-integration tests. However, before two variables can be tested for co-integration, they must be seen to be integrated of the same order.

A. Integration Tests

The dynamic property of a time series can be described by how often it needs to be differentiated to achive time-invariant linear properties and provide a stationary process. A series that has at least invariant mean and variance and whose autocorrelation has "short memory" is called I(0), denoting "integrated of order zero". 1/ A series which needs to be

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1 With "short memory" a small number of lagged observations explains current behavior.

differentiated Δ times to become I(0) is said to be integrated of order Δ, denoted as I(Δ).

The simplest example of a non-stationary series is the random walk:

$$X_t = X_{t-1} + e_t$$

where e_t is independent and normally distributed. In this case:

$$X_t = e_t + e_{t-1} + \ldots + e_1$$

assuming that $X_o = 0$, so X_t is the sum of past e_t no matter how long ago they occurred, that is, the series has a long memory. However, $X_t - X_{t-1} = e_t$ is stationary.

The order of integration is inferred by testing for unit roots. The most widely applied unit root tests are: (a) the Durbin-Watson test of Sargan and Bhargava (1983) (CRDW); and (b) the Dickey-Fuller test (DF) or Augmented Dickey-Fuller test (ADF) (Dickey and Fuller 1979, 1981). All test the null hypothesis that the series are I(1) i.e., H_o: X_t is I(1). The three statistics employed are calculable by least squares regression as follows: 1/

CRDW : $X_t = a + e_t$
H_o : X_t is I(1) if the DW statistic is below a critical value

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1/ Their critical values with one, two and three variables are provided by Engle and Granger (1987) and Granger and Newbold (1989).

DF: $\Delta e_t = a + \beta e_{t-1} + v_t$

H_o : X_t is I(1) if β is negative and its t-statistic is below a critical value. 1/

ADF : $\Delta e_t = a + \beta e_{t-1} + \sum_{i=1}^{n} \gamma_t \Delta e_{t-1} + v_t$

H_o : X_t is I(1) if β is negative and its t-statistic is below a critical value.

where e_t are the residuals from the X_t and are white noise and n in the ADF test is selected to be large enough to ensure the residuals v_t are white noise. A statistically significant, negative coefficient β signifies that changes in X_t or e_t can be reversed over time and that their levels are stable over the long-term.

The critical values for the three tests at the 99%, 95% and 90% significance levels are presented below. The critical values for the DF and ADF test statistic were obtained through Monte Carlo simulations, based on 100 observations and with 10,000 replications, under the assumption that Δe_t is identically and normally distributed.

1/ The test statistic is the t-statistic for Beta; the student t-distribution is not appropriate.

Critical Values of Unit Root Tests

Tests	Levels of Significance 90%	95%	99%
CRDW	0.322	0.386	0.511
DF	3.03	3.37	4.07
ADF	2.84	3.17	3.77

Source: Engle and Granger (1987).

In the case of non-autocorrelation in the residuals Δe_t, the ADF test is misspecified and has the wrong size, in comparison to the DF test since it estimates parameters that are truly zero. In the case of autocorrelation, the DF is misspecified and has the wrong size in comparison to the ADF test. The CRDW test performs better overall in both the non-autocorrelated and autocorrelated cases according to the power calculations of Engle and Granger (1987). However, its critical values are quite sensitive to the particular parameters within the null hypothesis as well as to the sample size. In order to avoid misleading results from these tests all three tests are applied.

One problem in the identification of the unit root of a time series is the existence of a trend. A misspecification can occur if it is assumed that a series y_t follows a random walk such as:

$$y_t = y_{t-1} + u_t \tag{1}$$

while the correct generating mechanism is:

$$y_t = a + bt + e_t \tag{2}$$

In the latter case y_t is assumed to be white noise around a deterministic trend. The test employed to detect whether the random walk is the proper specification vis-a-vis the trend is the Phillips test as suggested by Durlauf and Phillips (1988). The test uses the R^2 statistic and the Durbin-Watson statistic as follows: a high R^2 for the least squares regression (2) suggests a significant relationship between time (t) and a zero mean integrated dependent variable (y_t), while the Durbin-Watson statistic provides an asymptotically powerful statistic for exposing spurious regression. If the Durbin-Watson statistic is low, then equation (2) will be misspecified. More specifically, Durlauf and Phillips point out that the "asymptotic behavior of the Durbin-Watson statistic suggests that the probability of mistaking a non-stationary series for a stationary series about trend is not particularly great for reasonably large data sets", thus strongly reinforcing the recommendations of Sargan and Bhargava (1983) for the use of the Durbin-Watson statistic as a test for unit roots. Thus the Phillips test can be as follows: if the R^2 and Durbin-Watson statistic of equation (2) are high, then equation (2) is the correct specification vis-a-vis equation (1). The critical values for the Durbin-Watson statistic are the same as the ones used for the Durbin-Watson test of Sargan and Bhargava (1983), while the critical value for the R^2 statistic is obtained from the Monte Carlo simulations of Nelson and Kang (1981, 1983) and is approximately 0.44.

The three integration tests and the Phillips test described above were applied to nine primary commodity prices namely: cocoa, coffee, wheat, cotton, rubber, copper, lead, crude oil and silver. These commodities cover a broad spectrum from agricultural annuals and perennials to metals, energy and precious metals. 1/ However, there is no a priori reason why any two of these commodity prices should have a long-run stationary relationship.

Tables 1a and 1b report the CRDW, DF, and ADF test statistics for the nine commodities for both annual and monthly price series. The ADF test was also carried out after fitting various lags to the data, where the number of lags was sufficient to ensure that the residual v_t is white noise (the number of lags used, L, is reported in column 5 of Table 1). Results of the Lagrange Multiplier test for third-order residual autocorrelation, LM(3)--distributed as X^2 (3) in large samples, under the null hypothesis that there is no autocorrelation-- are presented in the sixth column of Tables 1a and 1b (the critical value at 95% level of significance for X^2 (3) is 7.81).

The integration results of the untransformed data in Tables 1a and 1b--i.e., price levels--reject the hypothesis that the price series tested are stationary at the 99% level of significance. The Phillips test results, the R^2 least squares regression of equation (2) and the Durbin-Watson statistic (CRDW), are given in the line where (t) appears after the series name. If CRDW is higher than 0.511 (the 99% significance level) with a relatively high

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1/ Detailed descriptions of the commodity price data used in this paper can be found in Annex I.

Table 1a: Integration Unit Root Test and Phillips Test:

Annual Series

		CRDW	R^2	DF	ADF	L	LM:$X^2(3)$
				Levels			
Cocoa		0.18		-1.30	-0.98	2	2.25
	(t)*	0.42	0.56	-2.24	-1.72	2	2.05
Coffee		0.16		-1.37	-0.90	2	1.01
	(t)	0.35	0.55	-1.91	-1.79	2	1.87
Cotton		0.20		-1.32	-1.28	4	1.81
	(t)	0.35	0.42	-2.01	-2.18	3	2.78
Lead		0.25		-1.32	-1.01	3	0.28
	(t)	0.43	0.42	-2.20	-1.95	3	2.01
Oil		0.06		-0.45	-0.71	1	2.26
	(t)	0.16	0.65	-1.67	-1.65	1	2.63
Silver		0.07		-0.88	-0.80	2	0.58
	(t)	0.49	0.85	-2.17	-1.68	2	2.01
Wheat		0.16		-0.98	-0.42	4	1.45
	(t)	0.39	0.60	-2.14	-2.14	2	2.05
Copper USA		0.11		-0.52	-0.91	1	3.97
	(t)	0.76	0.87	-2.96	-3.45	1	1.33
Rubber		0.50		-2.27	-0.92	4	3.59
	(t)	0.65	0.74	-2.97	-2.79	4	3.23
				First Differences			
Cocoa		1.79		-6.18	-3.63	2	0.73
Coffee		2.12		-6.51	-3.27	2	1.88
Cotton		2.24		-6.89	-2.24	3	1.37
Lead		1.65		-5.35	-3.25	3	1.46
Oil		1.64		-5.13	-3.45	2	0.71
Silver		1.75		-5.38	-3.19	3	0.81
Wheat		1.42		-4.35	-4.03	3	1.81

* Line (t) signifies the regression $P_t = a + b*t + \varepsilon_{(t)}$.

L is the number of lags used in the ADF test.

Table 1b: Integration Unit Root Test and Phillips Test:

Monthly Series

		CRDW	R^2	DF	ADF	L	LM:X^2(7)
			Levels				
Cocoa		0.02		-2.44	-1.86	2	5.14
	(t)	0.03	0.29	-1.59	-1.26	2	5.46
Coffee		0.02		-1.64	-2.06	3	3.63
	(t)	0.04	0.55	-1.34	-2.13	3	3.69
Cotton		0.02		-1.97	-2.53	3	5.33
	(t)	0.03	0.35	-1.16	-2.39	3	5.41
Lead		0.03		-1.99	-1.89	1	1.89
	(t)	0.04	0.21	-1.83	-1.97	1	1.71
Oil		0.08		-1.76	-1.94	3	1.56
	(t)	0.02	0.64	-0.16	-0.74	3	1.51
Silver		0.02		-2.38	-1.63	3	6.44
	(t)	0.05	0.53	-1.89	-1.63	3	5.51
Wheat		0.02		-1.61	-1.79	1	1.98
	(t)	0.03	0.42	-1.48	-1.97	1	1.79
Copper USA		0.08		-1.04	-1.95	3	4.70
	(t)	0.09	0.13	-1.50	-2.39	3	4.80
Rubber		0.02		-1.20	-1.65	6	5.58
	(t)	0.04	0.53	-1.47	-2.27	6	5.88
			First Differences				
Cocoa		1.65		-14.24	-9.02	2	4.47
Coffee		1.29		-10.81	-7.69	3	2.93
Cotton		0.86		-8.09	-6.06	3	3.51
Lead		1.46		-12.05	-9.43	6	1.68
Oil		1.85		-14.41	-6.37	3	1.59
Silver		1.39		-14.05	-7.69	3	6.26
Wheat		1.29		-10.65	-8.57	3	3.08

* Line (t) signifies the regression $P_t = a + b*t + u_{(t)}$.

L is the number of lags used in the ADF test.

R^2 (higher than 0.44), the series follow regression (2) rather than (1), i.e., they are white noise around a deterministic trend. 1/ For the annual series, Table 1a, copper and rubber have a deterministic trend. Therefore, it can be said that copper and rubber are I(0) with a deterministic trend. From the test results on the first-differenced price series (excluding copper and rubber) it can be said with 99% confidence that the annual and monthly series are stationary. So, given that the commodity prices were differenced once in order to achieve stationarity--i.e., become I(0)--they are integrated of order one, i.e., they are I(1).

In Tables 2a and 2b similar tests are applied to macroeconomic variables.

The macro-economic variables used were the weighted GNP of the G-7 countries (GNP7); the index of industrial production of the G-7 (11P); the CPI of the G-7 weighted by their GNP shares (CPIG7); the US dollar exchange rate vis-a-vis the Deutch mark, the yen, and the British pound, equally weighted (EXR); the US M2 measure of money supply plus the US dollar reserves held by foreign central banks (MS); the 3-month US Treasury bill rate (TBR); and the S & P 500 stock index (S&P500). The variable representing the dollar base money supply (MS) serves (in difference) as an expectation variable for inflation. All macroeconomic variables were found to be I(1), except for the CPI of the G-7 which was found to be I(2). None of the series can be said to be

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1/ According to the analysis of Durlauf and Phillips (1988), higher importance is placed on the value of the Durbin-Watson statistic (CRDW) than on the R^2 statistic.

Table 2a: Integration Unit Root Test for Macroeconomic Variables

Annual Series

	CRDW	DF	ADF	L	LM:$X^2(7)$
		Levels			
TBR	0.184	-1.651	-1.546	3	0.474
LnIIP	0.022	-1.008	-2.226	4	1.326
LnCPIG7	0.009	2.329	-0.431	7	4.889
LnCPIG7T (1)	0.050	-1.547	-3.054	7	4.047
LnEXR	0.182	-0.149	-0.207	4	0.593
LnGNPG7	0.015	0.377	-2.354	7	1.326
LnMS	0.008	4.151	-0.204	5	1.885
LnS&P500	0.036	-1.280	-1.635	1	2.495
		First Differences			
ΔTBR	1.706	-5.246	-3.341	3	0.898
ΔLnIIP	2.389	-7.988	-3.783	3	4.781
ΔLnCPIG7	0.420	-2.384	-1.540	5	0.454
Δ^2LnCPIG7T	1.867	-9.906	-4.111	3	4.336
ΔLnEXR	1.048	-3.606	-4.140	3	0.862
ΔLnGNPG7	2.057	-6.562	-2.084	6	2.006
ΔLnMS	0.807	-3.915	-1.698	3	2.240
ΔLnS&P500	1.989	-6.142	-3.809	2	6.780

(1) The CPIG7 variable includes a trend which is proven in the estimation:

$$CPIG7 = -2.827\ (0.049) + 0.050T\ (0.002) + e_t.$$

Δ Indicates that the first difference of the variables has been taken.

Δ^2 Indicates second differencing.

Table 2b: Integration Unit Root Test for Macroeconomic Variables

Monthly Series

	CRDW	DF	ADF	L	LM:X^2(3)
		Levels			
TBR	0.07	-2.06	-1.63	6	15.05
LnIIP	0.03	-0.38	-0.27	2	2.94
LnCPIG7	0.01	-2.86	-1.17	9	5.68
LnMS	0.01	-1.66	-1.35	4	10.47
LnEXR	0.02	-0.62	-1.17	3	2.48
LnS&P500	0.22	-1.26	-0.07	6	9.93
		First Differences			
ΔTBR	1.48	-11.74	-7.68	6	15.76
ΔLnIIP	0.98	-8.76	-5.91	2	2.57
ΔLnCPIG7	0.71	-7.08	-3.30	4	11.74
ΔLnMS	0.77	-7.49	-4.14	4	9.48
ΔLnEXR	1.83	-10.89	-7.64	2	2.17
ΔLnS&P500	1.26	-19.50	-6.80	4	9.71

generated by the process described in equation (2), i.e., I(0) around a deterministic trend. The non-rejection of the unit root hypothesis in the macroeconomic variables (with the exception of the CPI) is consistent with the finding of previous studies examining the existence of unit roots in aggregate macroeconomic variables (e.g., Nelson and Plosser 1982).

B. Co-integration Tests

After establishing that the commodity prices with the exception of copper and rubber are I(1), the next step is to see whether they are co-integrated. The technique of co-integration tests is based on Engle and Granger (1987). Two series, Y and X, which are non-stationary in levels are cointegrated if they are stationary in first differences and there exists a linear combination of the levels:

$$Y_t - K X_t = Z_t$$

which is stationary (K is called the co-integrated parameter). 1/ So that although Y and X may have infinite variances, the linear combination Z_t is stationary, i.e., Z_t is I(0). As Z_t has such different temporal properties from either X_t or Y_t it follows that X_t and Y_t "must have a very special

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1/ Engle and Granger's (1987) treatment of co-integrated series is more general in that they allow for a higher order of non-stationarity in the series, but the above definition is sufficent for the purposes of this paper.

relationship". That is, X_t and Y_t have dominating low-frequencies or long-term components which virtually cancel out to produce Z_t. 1/

To test whether the series are co-integrated, a two-stage test similar to that applied to test for integration is followed. In the first stage, the coefficient K is estimated using OLS; in the second stage the resulting series $Z_t = Y_t - KX_t$ is tested for I(0) using the integration tests described previously. If the series are co-integrated, a robust estimate for K can be expected. Phillips (1986, 1987) has shown that the estimated parameters of co-integrated variables converge in the limit to constants. Stock (1984) proved that the estimated parameter K in the co-integration regression of the first stage is consistent with the real parameter K, and the convergence is very rapid. This result implies that if the sample size is relatively large and Y_t and X_t are indeed co-integrated in the true data-generating process, the two-step procedure for testing co-integration of Engle and Granger (1987) seems to be appropriate. However, if the R^2 and DW are low in the co-integration regression, large biases in the estimate of K can occur and the two-step procedure is less than fully consistent. The tests for co-integration have as the null hypothesis that the two series are co-integrated.

Tables 3a and 3b present the cointegration test results between each commodity and all others for both annual and monthly series. These results may appear to be repetitious because we have tested variables X_t and Y_t and then repeated the test for co-integration between Y_t and X_t when we would

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1/ See also discussion on pg. 5 above.

Table 3a: Unit Root Tests of The Cointegrating Regressions (1)

Annual Series

	CRDW	DF	ADF	L	LM:$X^2(3)$
Cocoa					
Coffee	1.29	-4.82	-3.36	2	0.82
Cotton	0.91	-3.34	-4.29	3	2.95
Lead	0.79	-2.99	-3.815	2	0.84
Oil	1.02	-3.59	-3.17	3	0.99
Silver	0.74	-3.09	-3.02	1	3.55
Wheat	0.84	-3.07	-3.19	4	1.82
Coffee					
Cocoa	1.27	-4.96	-3.41	2	0.67
Cotton	0.99	-3.91	-4.13	3	1.01
Lead	0.75	-2.89	-3.92	1	0.84
Oil	1.05	-4.22	-3.83	2	2.11
Silver	0.67	-2.79	-2.93	1	1.42
Wheat	0.78	-2.94	-3.64	2	1.04
Cotton					
Cocoa	0.93	-3.37	-3.92	3	1.52
Coffee	1.03	-3.87	-3.43	3	0.77
Lead	0.97	-3.43	-2.99	2	1.02
Oil	1.05	-3.67	-3.06	3	2.06
Silver	0.48	-2.43	-2.96	3	0.99
Wheat	1.12	-3.95	-2.71	2	1.84
Lead					
Cocoa	0.87	-3.07	-3.51	2	2.29
Coffee	0.83	-3.05	-4.51	1	1.85
Cotton	1.03	-3.52	-3.64	2	3.48
Oil	0.69	-2.69	-4.01	1	0.91
Silver	0.65	-2.75	-3.28	3	1.89
Wheat	0.83	-3.06	-3.23	3	1.89

Table 3a: Unit Root Tests of the Cointegrating Regressions (continued)

Oil					
Cocoa	0.89	-3.24	-4.07	1	3.41
Coffee	0.95	-3.77	-3.19	2	0.44
Cotton	0.90	-3.30	-2.78	3	1.99
Lead	0.49	-2.31	-3.39	2	0.98
Silver	0.38	-2.42	-2.98	7	3.19
Wheat	0.84	-3.10	-3.51	1	1.24
Silver					
Cocoa	0.63	-2.91	-3.05	4	3.87
Coffee	0.58	-2.53	-2.96	1	5.73
Cotton	0.35	-2.20	-3.11	3	0.61
Lead	0.65	-2.75	-3.62	1	0.06
Oil	0.39	-2.62	-3.07	7	5.42
Wheat	0.55	-2.74	-2.90	3	0.51
Wheat					
Cocoa	0.83	-2.95	-3.60	3	1.31
Coffee	0.77	-2.91	-3.74	2	1.68
Cotton	1.07	-3.85	-3.35	2	3.01
Lead	0.73	-2.87	-2.88	3	7.51
Oil	0.94	-3.23	-2.89	3	3.65
Silver	0.63	-2.73	-2.93	2	0.93

Table 3b: Unit Root Tests of the Cointegrating Regressions

Monthly Series

	CRDW	DF	ADF	L	LM:$X^2(3)$
Cocoa					
Coffee	0.10	-2.71	-2.89	2	0.89
Cotton	0.08	-2.39	-3.10	4	3.76
Lead	0.04	-1.83	-2.94	13	2.85
Oil	0.06	-2.34	-2.84	10	1.57
Silver	0.05	-1.84	-2.89	12	2.61
Wheat	0.05	-1.90	-3.34	12	5.06
Coffee					
Cocoa	0.10	-2.30	-3.06	2	2.78
Cotton	0.05	-1.71	-3.03	10	6.35
Lead	0.05	-1.72	-2.85	13	4.64
Oil	0.06	-1.93	-3.63	10	6.26
Silver	0.07	-2.08	-3.42	10	3.53
Wheat	0.04	-1.53	-2.86	8	1.11
Cotton					
Cocoa	0.07	-2.06	-3.60	4	7.60
Coffee	0.05	-1.90	-3.81	7	6.60
Lead	0.06	-1.84	-3.07	4	11.55
Oil	0.07	-2.16	-3.37	1	10.19
Silver	0.10	-2.39	-3.72	3	8.04
Wheat	0.06	-1.70	-3.10	1	2.42
Lead					
Cocoa	0.05	-1.59	-3.26	10	6.61
Coffee	0.06	-2.05	-2.87	13	5.07
Cotton	0.07	-1.99	-2.93	10	6.98
Oil	0.06	-1.94	-2.85	12	6.56
Silver	0.08	-2.05	-2.91	13	7.31
Wheat	0.06	-2.02	-2.91	13	7.31

Table 3b: Unit Root Tests of the Cointegrating Regressions (continued)

Oil					
Cocoa	0.05	-1.72	-2.62	10	2.32
Coffee	0.05	-1.82	-3.32	10	5.47
Cotton	0.06	-1.89	-3.12	10	4.51
Lead	0.04	-1.46	-2.88	12	6.24
Silver	0.16	-3.21	-3.22	10	7.04
Wheat	0.07	-1.82	-2.96	12	4.29
Silver					
Cocoa	0.05	-1.85	-2.89	12	9.31
Coffee	0.08	-2.54	-3.02	10	2.96
Cotton	0.11	-2.66	-2.98	10	5.41
Lead	0.07	-2.23	-2.99	12	10.35
Oil	0.17	-3.59	-3.27	10	7.74
Wheat	0.09	-2.51	-2.96	11	8.17
Wheat					
Cocoa	0.04	-1.23	-3.24	11	8.76
Coffee	0.03	-1.49	-3.18	11	8.79
Cotton	0.06	-1.51	-3.86	11	8.86
Lead	0.04	-1.65	-2.85	10	1.62
Oil	0.08	-1.91	-2.89	12	1.81
Silver	0.08	-2.05	3.01	11	4.96

(1) The rejection region for the null of I(1) residuals is $[D.W. \varepsilon R|DW>C]$ with C = 0.511, 0.386 or 0.322, at significance level of 1%, 5% or 10%, respectively. Also, the rejection region for the same null hypothesis of the ADF test is $[t\varepsilon R|t<C]$ with C = -3.77, -3.17 or -2.84 at significance level of 1%, 5% or 10%, respectively.

expect that if, for example, cocoa is co-integrated with wheat, wheat would be co-integrated with cocoa. However, the repetition serves to check the robustness and consistency of the test results. The values of the tests presented for the pairs (X,Y) and (Y,X) are different, which is to be expected given the error occuring from the different normalizations. However, the test results are largely invariant to the choice of the normalizing variable. The results show a strong relationship between the commodity prices tested. For all the co-integrating regressions of the annual series (Table 3a) the Durbin-Watson statistic is large enough to reject the null hypothesis of I(1) residuals at even the 99% level of significance. This result is confirmed by examining both the Dickey-Fuller and the Augmented Dickey-Fuller test statistics for the existence of a unit root in the residuals of the co-integrating regressions. According to these two tests the null hypothesis of a unit root in the residuals is rejected for all primary commodity price pair combinations at or below the 90% level of significance.

For the co-integrating regressions of the monthly series of the primary commodity prices (Table 3b), the Augmented Dickey-Fuller test statistics suggest that co-integration cannot be rejected. But this result is not confirmed when examining the Durbin-Watson statistic. This discrepancy is expected in high-frequency series such as monthly series. These series do not present a pattern of frequent and considerable fluctuation, so the resulting first-order autocorrelation coefficient ρ is high, and D.W. $\approx 2\ (1-\rho)$ is very close to zero. In other words, the residuals of the monthly series tested exhibit a high degree of autocorrelation which leads to misspecification in both the D.W. and Dickey-Fuller tests. So, in this case, the D.W. and Dickey-Fuller have the wrong size in comparison to the Augmented Dickey-Fuller test.

Overall, therefore, these results are supportive of the hypothesis that the commodity prices under examination are co-integrated and that there is long-run co-movement between them. Tables 3a and 3b show that transitivity holds since, if X, Y, and X, Z, are co-integrated, then, equivalently, Y, Z, are also co-integrated. Note that in these tests copper and rubber prices are not included since it was found that they are integrated of degree zero with deterministic trend, i.e., they have different intertemporal characteristics from the rest of the commodities.

III. TESTING FOR EXCESS CO-MOVEMENT

The issue of short-run co-movement and excess co-movement is now examined. Do some otherwise unrelated commodity prices influence the movement of others in the short-run? Several studies have shown significant short-run impacts of macroeconomic shocks on commodity prices across the board but very little work has been done to show whether there is co-movement beyond that. 1/ Commodity traders and speculators consider it quite normal for commodity prices to move together for reasons other than the influence of macroeconomic shocks. They usually attribute this to "liquidity effects" or to "sympathetic speculative buying". For instance, a fall in the price of one commodity causes other commodity prices to fall mainly because it reduces the liquidity of speculators who are long in several commodities at once--speculators in futures sell other commodities to cover margin calls in the commodity in which they are long. "Sympathetic speculative buying" ("herd" behavior) may explain why when the events in the Persian Gulf in 1990 caused oil prices to rise, cocoa prices temporarily rose also. This section examines the short-run excess co-movement between commodity prices, based on the long-run stationary relationship established earlier.

1/ See Ghura (1990) and Barnhart (1989) among others.

Given that two prices, P_i and P_j, are found to be co-integrated with a co-integrating vector K, they can be written in an error-correction form. This equivalent characterization of co-integration is due to Engle and Granger (1987). When co-integration is established, an error-correction form provides more efficient parameter estimates than a vector-autoregressive (VAR) model in levels; while a VAR model in differences ignores information about the levels of the series and is therefore misspecified. The use of the error-correction form provides a formulation for assessing the short-term dynamics between two variables while keeping in mind the long-run relationship between these two variables. This approach permits the explanation of long- and short-run commodity price fluctuations to be merged, since the error correcting term of the "equilibrium" solution is imbedded in the short-run representation of the model. An error-correction form takes the following general expression: 1/

$$P_{i,t} - P_{i,t-1} = a\,(P_{j,t-1} - K\,P_{j,t-1}) + b\,(P_{j,t} - P_{j,t-1}) + \text{lagged}\,(\Delta P_i,\ \Delta P_j) + e_t \qquad (3)$$

where a, b, are estimable parameters, and e_t is a stationary error term. The usual interpretation of the error-correction form is that the change in P_i is due to the short-run effect from the change in P_j and to the last period's error, $[P_i - K\ P_j]$, of the co-integrating regression, which represents the

1/ For the specification of the ECM see also Nickell (1985) and Engle and Granger (1987).

long-run adjustment to past equilibrium. This error-correction equation is fundamental to the tests developed. Equation (3) implies two things. First, it indicates that the amount and direction of change in P_i and P_j take into account the size and sign of the equilibrium error $[P_i-KP_j]$ at period t-1; and second, it indicates if the term $b\,[P_{j,t} - P_{j,\,t-1}]$ is significantly different from zero (i.e., $b \neq o$), it (the term $b\,[P_j-P_{j,t-1}]$ can be used to predict $[P_{i,t} - P_{i,\,t-1}]$. The non-rejection of the b=o hypothesis in the restricted error-correction model (equation (3)), indicates that there is no short-run co-movement. However, since the linear combination of the spot prices of commodity P_i and commodity P_j is stationary, then there may be a set of information Ω from which both P_i and P_j draw their information, and which makes them move together.

Since the commodities are believed to be largely unrelated in terms of cross price elasticities of supply and demand, the set of information Ω should consist of shocks which have impacts across all commodities, that is, it should consist of macroeconomic variables such as the CPI, the index of industrial production (IIP), the money supply, exchange rates, interest rates and the S & P 500 stock index. The important role these macroeconomic variables play in the formation of primary commodity prices has been suggested in the theory and tested empirically by Barnhart (1989), Palaskas and Varangis (1989), Gilbert and Palaskas (1990), Ghura (1990), Chambers and Just (1982), and Frankel and Hardouvelis (1985), among others.

If P_i and P_j incorporate information from the elements of the set Ω and if $b[P_{j,t} - P_{j,t-1}]$ significantly explains $[P_{i,t} - P_{i,t-1}]$, then the variation in the latter can be explained directly by using the elements belonging to the subset Ω. Therefore, the effects of macroeconomic variables (as elements of Ω) can be incorporated in equation (3) as follows:

$$P_{i,t} - P_{i,t-1} = a\,(P_{i,t-1} - KP_{j,t-1}) + b\,(P_{j,t} - P_{j,t-1}) + \text{lagged}\,(\Delta P_i,\ \Delta P_j) \quad (4)$$
$$+ \text{current and lagged}\,(\Delta MV) + e_t$$

where MV signifies the set of macroeconomic variables. The inclusion of macroeconomic variables into equation (3) (giving equation (4) as the unrestricted version of the model is expected to replace the explanatory power of $b[P_{j,t} - P_{j,t-1})$, i.e., making b = o. The case where $b \neq o$ suggests that elements of information outside of those belonging in Ω make P_i and P_j move together. In other words, variations in the price of commodity j, P_j, explain variations in the price of commodity i, P_i, above and beyond what macroeconomic variables explain. This would suggest that the prices of commodities i and j have excess co-movement.

The results from estimation of the restricted version of the error-correction model (equation (3)) for the annual and monthly series are reported in detail in Tables A1 and A2 (see Annex II). They show that as the frequency over which price changes are measured decreases from monthly to yearly, the proportion of price variation which can be attributed to macroeconomic variables rises. The diagnostic tests for serial correlation, normality and stability suggest no evidence of autocorrelation, non-normal errors (except for six cases which will be discussed later), or instability in the specifications of the annual series. On the other hand, the results for a number of monthly series suggest non-normal errors. One possible explanation for this finding is that there is high-frequency, mean-reverting noise in the monthly price series. Therefore, neither macroeconomic variables nor prices of other commodities explain a large fraction of individual monthly price changes. The existence of non-normal errors indicates that in the application of the standard tests for testing the hypothesis of no excess co-movement may be inappropriate.

The results of the likelihood ratio ($X^2(1)$) testing for excess co-movement are reported in Table 4. The X^2 test is used to test the restriction b = 0 in equation (4). The log-likelihood ratio values of the first part of the table--annual series--reject the null hypothesis of no excess co-movement for only nine pairs of prices out of 42. Of these nine pairs, eight pairs give "symmetrical results" and one pair is nonsymmetrical. The expression "symmetrical results" means that test results on the pairs (X, Y) and (Y, X) are the same. Pairs which give symmetical results are wheat with oil and cotton, silver-cotton and coffee-cocoa. The pair with nonsymmetrical results is lead-coffee. The presence of excess co-movement between the prices of cocoa and coffee may be attributed to some degree of substitutability between them, that is, they are produced in the same regions, so they share some information related to supply, such as weather conditions. The 1976-77 boom in their prices, due to supply shocks caused by coincidental weather conditions, and the subsequent price decline in the early 1980s dominated in the tests performed, leading to acceptance of the excess co-movement

Table 4: Testing for Excess Co-movement log-Likelihood

Ratio Test ($X^2(1)$)

	Cocoa	Coffee	Cotton	Lead	Oil	Silver	Wheat
				Annual Series			
Cocoa	-	20.86**	0.21	1.23	3.39	1.65	2.31
Coffee	20.98**	-	2.51	17.65**	0.34	0.63	0.23
Cotton	3.37	0.21	-	2.11	0.02	11.76**	52.75**
Lead	1.27	1.03	0.69	-	2.57	2.93	3.30
Oil	2.50	1.15	0.62	1.68	-	0.41	14.54**
Silver	2.67	3.04	9.47**	2.27	3.29	-	0.94
Wheat	0.25	1.35	11.27**	0.49	7.42**	2.09	-
				Monthly Series			
Cocoa	-						
Coffee		-					
Cotton			-	8.33**	11.68*	8.75**	10.31**
Lead			9.45**	-		7.88**	7.35**
Oil			14.35**		-	11.19**	
Silver			8.30**	8.30**	16.05**	-	
Wheat			7.11**	8.33**			-

* At 5% level of significance.
** At 1% level of significance.

hypothesis. Similarly, the excess co-movement between cotton and wheat may be attributed to some degree of substitution in production in certain producing areas, while for wheat and oil it is due to the significant coincidental increases in these prices in 1973 and 1979-80 which dominate the samples of annual data. However, as stated earlier, for six pairs the hypothesis of non-normal errors was rejected. These pairs are coffee-lead, cotton-oil, oil-lead, cotton-silver, lead-coffee, and wheat-oil. For the last three pairs we could not also reject the hypothesis of excess co-movement. So, if we accept the results from the tests where the non-normality hypothesis is rejected, the no excess co-movement hypothesis is accepted for only 6 out of 39 pairs. In this situation, the only pair with symmetrical results for which the hypothesis of no excess co-movement is rejected is cocoa-coffee.

The results of the second part of Table 4--the monthly series--suggest that excess co-movement can be established between 14 unrelated pairs of prices. The results are symmetrical for all the pairs, so excess co-movement could not be rejected for seven commodity price pairs out of 21. The seven commodity price pairs for which excess-co-movement cannot be rejected are: cotton with lead, oil, silver and wheat; lead with silver and wheat; and oil-silver. For the rest of the commodity pairs, for which test results are not shown, the effect of the price of the other commodity was not significant to begin with; i.e., in equation (3) the hypothesis that b = 0 could not be rejected at even the 99% level of significance. For these pairs the X^2 test was not applicable. Thus, for the monthly data, if pairs of commodity prices are found to move together in the short-run, the hypothesis of excess co-movement cannot be rejected. However, as stated previously, the λ^2 test for normality rejected the hypothesis of normal errors for a large number of commodities in the monthly series. The non-normality hypothesis was rejected for all of the 14 pairs tested. The implication of the rejection of normality is that the tests for excess co-movement performed have the wrong size. Not knowing the correct distribution of the errors we cannot apply the appropriate critical values for hypothesis testing. So, for the monthly regressions the test results are biased, and the evidence regarding excess co-movement is still under question.

Overall, our findings about excess co-movement are not consistent with those of Pindyck and Rotemberg (1988). Where there are non-normal errors the test results are in doubt. For the cases of normal errors, the no excess co-movement hypothesis could not be rejected in the majority of the cases. Consequently, we view with caution Maddala's (1990) suggestion, based on Pindyck and Rotemberg's results, that in the formation of price expectations the price movements of even unrelated commodities should be taken into account.

IV. SUMMARY AND CONCLUSIONS

In this paper, the recently developed technique of testing for co-integration in time series and the dynamic error-correction specification are applied to test the hypotheses of co-movement and excess co-movement between primary commodity prices. The tests are applied to a range of largely unrelated commodities in both monthly and annual data.

The test results support the hypothesis of co-movement between primary commodity prices, which is consistent with the findings of Pindyck and Rotemberg (1988). However, overall our test results seem not to support the hypothesis of excess co-movement. They suggest that, at least in the case of the annual data common shocks explain almost all the co-movement between commodity prices. This finding is not consistent with that of Pindyck and Rotenberg. The general finding of no excess co-movement has its exceptions. Among the annual series, 9 out of 42 pairs, and among the monthly series, 14 out of 42 pairs are found to have excess co-movement. However, we cast doubt on the results from the monthly series since for all monthly regressions the normality hypothesis of the errors of the regressions was strongly rejected. The same applies to six pairs in the annual series, three of which we could not also reject the hypothesis of no excess comovement.

While the macroeconomic variables explain a high proportion of the variation in most of the annual commodity prices, their explanatory power is reduced as we move from low- to high-frequency series, that is, from annual to monthly data. (Pindyck and Rotemberg also found that the amount of co-movement explained by macroeconomics variables declines as they moved from low- to high-frequency series.) Moreover, in the tests for monthly series it is found that neither the macroeconomic variables nor the other commodity prices seem to explain much of the variation in the price of a commodity. Still, for one third of the cases (in the monthly series) the hypothesis of excess co-movement cannot be rejected. However, the existence of non-normal errors in the monthly series leads to distortions in the size of the tests for excess co-movement.

In the cases of non-normal errors, in the annual but particularly in the monthly regressions, the distribution of errors is unknown causing distortions in the size and subsequently in the power properties of the tests applied. That is, the critical values on which the tests are based are not necessarily the correct ones at the stated levels of significance. Rejection of the non-normality hypothesis was noticably present in most of the regressions (all in the case of monthly series) in which the no excess co-movement hypothesis could not be rejected. So, one needs to view our results with caution when non-normality in the errors of the regressions is present.

While for the annual price series we feel that a general conclusion can be drawn, for the monthly series the presence of non-normal errors causes problems in the application of the proposed tests, leaving us with inconclusive results. Concerning the non-normality of errors in the monthly price series we plan to conduct further research on whether this non-normality and also excess co-movement are due to seasonal factors in the monthly time series.

As a closing remark we would like to offer an additional, though hard to test, alternative explanation of excess co-movement to those presented by Pindyck and Rotemberg. Their explanations mostly deal with "herd" behavior of commodity traders. Our alternative explanation suggests the possibility that traders take time to distinguish between macro shocks and commodity-specific supply shocks. If a supply shock occurs which affects one or more commodity markets then commodity traders may misinterpret this shock as a macro shock and may go long or short on other commodities. Eventually, the correct information becomes available and adjustments follow.

ANNEX I: DATA DESCRIPTION

Annual and monthly data were obtained for the period 1950-89. The description of the prices used is as follows:

Cocoa:	International Cocoa Organization (ICCO) daily indicator price.
Coffee:	International Coffee Organization (ICO) indicator price for other mild arabicas, average New York and Bremen/Hamburg markets, ex dock.
Cotton:	Middling 1 inch, Orleans/Texas.
Lead:	London Metal Exchange (LME), refined, 99.97% purity, settlement price.
Oil:	Average spot price of OPEC crude oils.
Silver:	Handy & Harman, 99.9% grade refined, New York.
Wheat:	No. 2, soft red winter, export price delivered at the Gulf port for prompt or 30-day shipment.
Copper:	Producers' Price of Electrolytic (wirebar) copper, delivered U.S. destinations.
Rubber:	No. 1, in bales, spot, New York.

ANNEX II: ERROR-CORRECTION MODEL RESULTS

Table A1: Error Correction Model
Annual Data

	a Coefficient	Standard Error	b Coefficient	Standard Error	R^2	D.W.	Test for Normality $X^2(2)$
Cocoa							
Coffee	-0.174	0.039	0.754	0.148	0.469	1.79	1.52*
Cotton	-0.136	0.038	0.646	0.201	0.368	1.72	1.22
Lead	-0.103	0.049	0.414	0.202	0.259	1.76	0.33
Oil	-0.172	0.048	0.332	0.141	0.321	1.88	2.06
Silver	-0.123	0.046	0.313	0.159	0.233	1.84	3.75
Wheat	-0.082	0.049	0.212	0.286	0.110	1.42	3.77
Coffee							
Cocoa	-0.129	0.031	0.481	0.108	0.422	1.98	1.17*
Cotton	-0.128	0.034	0.244	0.180	0.283	2.11	1.26
Lead	-0.251	0.030	0.379	0.162	0.184	1.97	9.94
Oil	-0.196	0.044	-0.027	0.116	0.406	2.48	0.95
Silver	-0.087	0.037	0.025	0.142	0.138	2.00	0.70
Wheat	-0.103	0.036	0.006	0.226	0.197	2.10	5.92
Cotton							
Cocoa	-0.095	0.027	0.332	0.097	0.356	1.80	2.11
Coffee	-0.078	0.031	0.204	0.135	0.146	1.90	5.34
Lead	-0.357	0.127	0.196	0.116	0.267	2.21	5.20
Oil	-0.132	0.023	0.453	0.079	0.561	2.06	6.57
Silver	-0.086	0.023	0.349	0.023	0.463	2.04	13.57*
Wheat	-0.096	0.027	0.627	0.141	0.447	2.09	2.53*
Lead							
Cocoa	-0.529	0.127	0.361	0.121	0.432	2.16	3.89
Coffee	-0.426	0.130	0.438	0.141	0.387	2.07	7.43*
Cotton	-0.561	0.157	0.623	0.189	0.487	1.98	1.94
Oil	-0.548	0.159	0.379	0.135	0.330	1.79	2.60
Silver	-0.505	0.142	0.382	0.133	0.378	1.97	0.26
Wheat	-0.314	0.146	0.509	0.223	0.494	1.44	1.03
Oil							
Cocoa	-0.249	0.086	0.396	0.168	0.271	2.06	5.06
Coffee	-0.194	0.104	0.063	0.232	0.126	2.05	1.08
Cotton	-0.299	0.079	0.445	0.207	0.613	2.02	3.68
Lead	-0.219	0.062	0.402	0.189	0.340	1.69	7.77
Silver	-0.234	0.087	0.555	0.147	0.400	1.75	5.69
Wheat	-0.403	0.063	0.495	0.195	0.726	2.09	0.76*

Table A1 Error Correction Model
(Continued)

Silver							
Cocoa	-0.196	0.084	0.317	0.154	0.186	1.69	3.69
Coffee	-0.113	0.059	0.132	0.194	0.186	1.93	0.51
Cotton	-0.231	0.090	0.945	0.225	0.374	1.81	2.22*
Lead	-0.249	0.078	0.535	0.166	0.332	1.87	4.35
Oil	-0.195	0.089	0.563	0.139	0.326	1.82	0.83
Wheat	-0.230	0.089	0.911	0.231	0.359	1.97	2.84
Wheat							
Cocoa	-0.420	0.128	0.208	0.192	0.319	1.91	4.72
Coffee	-0.391	0.131	0.166	0.122	0.272	1.98	5.94
Cotton	-0.778	0.139	0.635	0.106	0.650	2.21	3.29*
Lead	-0.344	0.112	0.295	0.103	0.388	1.96	3.66
Oil	-0.987	0.248	0.551	0.107	0.447	1.95	7.07*
Silver	-0.408	0.134	0.288	0.089	0.406	1.91	5.18

The critical value at $X^2(2)$ at 95% is 5.99.

* Pairs for which the no excess co-movement hypothesis is rejected.

Table A.2: Error Correction Model
(Monthly Data)

	a Coefficient	Standard Error	b Coefficient	Standard Error	R^2	D.W.	Test for Normality $X^2(2)$
Cotton							
Lead	-0.029	0.010	0.102	0.037	0.362	1.81	18.49
Oil	-0.046	0.014	0.095	0.027	0.371	1.89	31.25
Silver	-0.042	0.012	0.064	0.025	0.366	1.86	32.96
Wheat	-0.029	0.011	0.145	0.048	0.362	1.79	24.32
Lead							
Cotton	-0.041	0.016	0.195	0.089	0.107	1.92	13.90
Silver	-0.101	0.045	0.157	0.044	0.149	2.01	26.05
Wheat	-0.026	0.014	0.235	0.061	0.194	1.95	8.32
Oil							
Cotton	-0.051	0.011	0.331	0.124	0.129	1.98	36.83
Silver	-0.046	0.014	0.138	0.055	0.100	1.90	66.92
Silver							
Cotton	-0.046	0.016	0.295	0.132	0.098	1.76	68.49
Lead	-0.049	0.013	0.292	0.090	0.141	1.76	26.09
Oil	-0.068	0.022	0.211	0.060	0.159	1.76	83.30
Wheat							
Cotton	-0.031	0.013	0.224	0.076	0.189	2.01	31.90
Lead	-0.025	0.010	0.077	0.036	0.156	2.01	53.24

The critical value of $X^2(2)$ at 95% is 5.99.

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